Current Controlled Inkjet-Printed h-BN Memristors Enabling Reliable Stateful Logic-in-Memory

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The exponential increase in energy consumption resulting from the development of artificial intelligence systems poses a substantial sustainability challenge [1]. Memristors emerge as the fundamental electronic device capable of enabling low-power neuromorphic applications. In specific, inkjet-printed memristors stand out due to their low material waste process, economic viability, and compatibility with flexible substrates, facilitating the development of flexible and biocompatible applications [2,3].
In this work, we present a hexagonal boron nitride (h-BN)-based inkjet-printed memristor. The results obtained from the electrical characterization of the devices show volatile and non-volatile resistive switching (RS) behaviour. At higher currents (above 10 μA) the devices show stable non-volatile RS with a high HRS/LRS ratio. The same devices when operated at much lower currents (below 1 μA) exhibit volatile RS. Endurance tests have been conducted under a current-controlled approach where a Howland-based current source is utilized. Both in the non-volatile and volatile regime a record endurance on inkjet-printed memristors is achieved of 70,000 and 2.2 million cycles with minimum overlap. The obtained results not only demonstrate exceptional endurance, reliability and operation under low currents but also opens the avenue for the implementation of current-controlled neuromorphic applications.
To demonstrate the applicability of this approach, a current-controlled stateful logic-in-memory NOR gate is presented. The MAGIC gates are subject to stringent operational voltage pulse conditions [4,5], which are challenging to meet due to the inherent variability of resistive switching devices. Consequently, the number of experimental demonstrations of these gates is limited. Our proposed NOR gate addresses this issue by employing a current-controlled approach, which expands its operational window significantly. The proposed NOR gate has been experimentally validated using inkjet-printed h-BN memristors, achieving 120 consecutive cycles without any computational errors.

References

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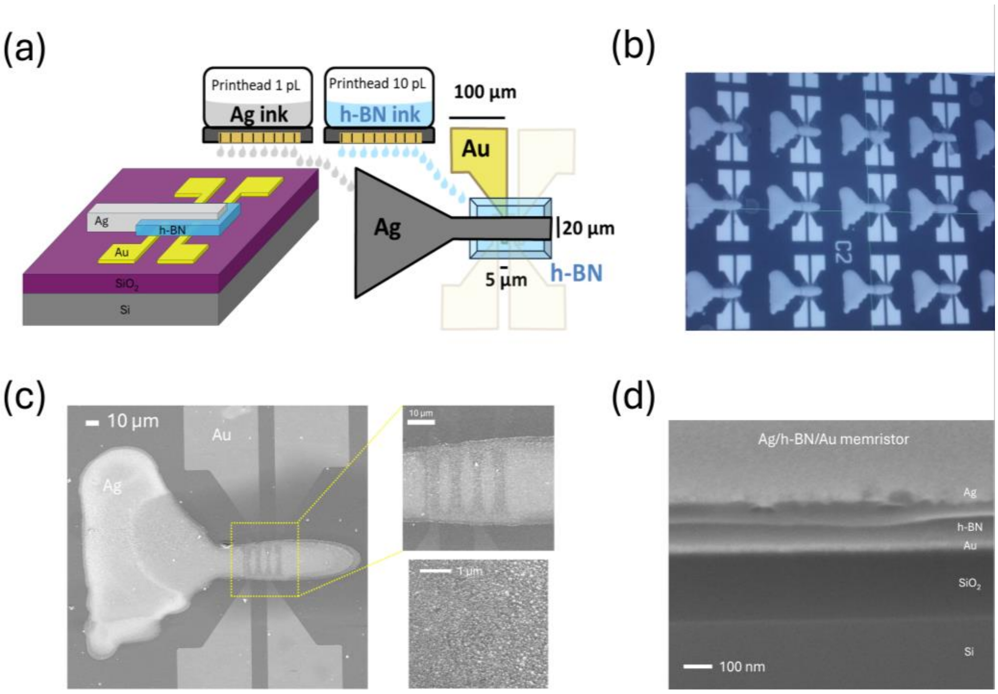

Figure 1: a) Schematic and dimensions of the fabricated inkjet-printed Ag/h-BN/Au memristors. (b) Optical image of a batch of memristors exhibiting a high uniformity. (c) SEM images of the memristors. Left image, top view of the whole structure. Top-right image is an insight on the active area of the device. Bottom-right image shows the deposited Ag nanoparticles of the top-electrode. (d) Cross-section SEM image of the Ag/h-BN/Au memristor stack.

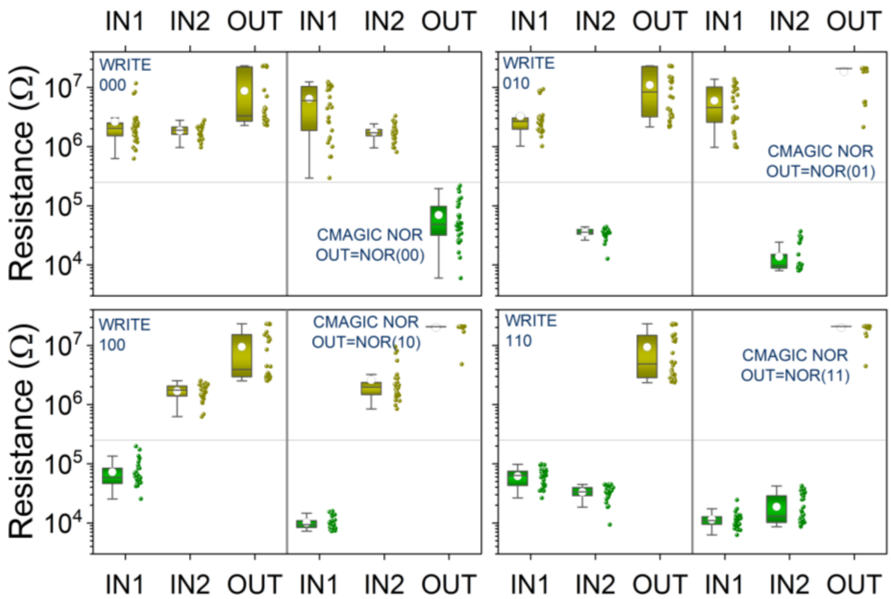

Figure 2: Experimental results of 120 cycles of the CMAGIC NOR attempts measured on Ag/h-BN/Au memristors. For each box, left part is the result after initial writing operation of IN1, IN2 and OUT, and right the result after proper Boolean execution using CMAGIC architecture. Yellow color indicates 0 logic state (HRS) and green color 1 logic state (LRS).